Physica B 407 (2012) 1203–1208

Contents lists available at SciVerse ScienceDirect

Physica B

journal homepage: www.elsevier.com/locate/physb

An X- and Q-band Gd^{3+} EPR study of a single crystal of $EuAlO_3$: EPR linewidth variation with temperature and low-symmetry effects

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ARTICLE INFO

Article history:
Received 29 August 2011
Received in revised form
11 January 2012
Accepted 13 January 2012
Available online 20 January 2012

Keywords:
Gd^{3+} ion
EPR
Spin-Hamiltonian parameters
EuAlO3
Van-Vleck paramagnet
X-band
Q-band
Lifetime broadening
Low symmetry

ABSTRACT

Detailed electron paramagnetic resonance (EPR) studies on a single crystal of Gd^{3+}-doped Van-Vleck compound $EuAlO_3$, potentially a phosphorescent/luminescent/laser material, with the Gd^{3+} ion substituting for the Eu^{3+} ion, were carried out at X-band (9.2 GHz) over the 77–400 K temperature range. They provide new physical results on magnetic properties of the Eu^{3+} ion in a low symmetry environment. The asymmetry exhibited by the variation of the Gd^{3+} EPR line positions for the orientations of the external magnetic field about the *Z* and *X* magnetic axes in the *ZX* plane was ascribed to the existence of low, monoclinic, site symmetry, as revealed by the significant values of the spin-Hamiltonian (SH) parameters b_4^1 and b_4^3, estimated by fitting all the observed EPR line positions at room temperature for the orientation of the magnetic field in the magnetic *ZX* plane using a least-square fitting procedure. The temperature dependence of the Gd^{3+} EPR linewidth is interpreted to be due to the "life-time" broadening, caused by dynamical exchange and dipolar interactions between the impurity Gd^{3+} ions and the host Eu^{3+} ions.

1. Introduction

$RAlO_3$ (R=rare earth) single crystals, characterized by the perovskite structure at and below room temperature, are interesting due to their phosphorescence and luminescence properties [1,2] as well as for their use as laser materials [1]. There exists further interest in perovskite-like compounds because of possessing a structure similar to that of manganites, which exhibit giant magnetostriction. Their peculiarities can be investigated in mixed compounds, where Al ions are partly replaced by Mn [3,4] ions. A detailed electron paramagnetic resonance (EPR) investigation of the Gd^{3+} ion in the isostructural crystal $LaGaO_3$ was recently reported by Vazhenin et al. [5]. Low symmetry effects in Gd^{3+} and Fe^{3+} spectra in $YAlO_3$ were also analyzed with the use of maximum invariant components (MIC) in Ref. [6]. Physical properties of $EuAlO_3$ have not yet been investigated extensively. A preliminary investigation of Gd^{3+} EPR spectra in an $EuAlO_3$ single crystal was carried out by Andronenko et al. [7]. In addition, EPR studies on the Cr^{3+} ion in $EuAlO_3$ have been reported [8], as well as those on Gd^{3+} in the isostructural $LaAlO_3$ and $YAlO_3$ crystals [9,10]. A relevant detailed EPR study of the Gd^{3+} ion in monoclinic $La_2Si_2O_7$ and $LaNbO_4$ crystals, which are also characterized by a low (C_s, and C_2, correspondingly) point symmetry of the Gd^{3+} ion and exhibit low-symmetry effects, was reported by Misra and Andronenko [11] and Misra et al. [12].

Europium aluminate ($EuAlO_3$) is an insulating Van-Vleck paramagnet, whose paramagnetism is due to the admixture of the levels of the $^7F_1$ term, split by the orthorhombic crystal field into three singlets (281, 359, and 479 cm^{-1}), in the singlet ground state $^7F_0$ [13], which by itself is non-magnetic. This admixture makes it paramagnetic, known as Van-Vleck paramagnetism. For a review of the peculiarities of magnetic resonance in Van-Vleck paramagnets, see Aminov et al. [14].

This paper reports a detailed EPR investigation on the Gd^{3+} ion in $EuAlO_3$ single crystal at X-band (9.22 GHz). The EPR spectra are recorded for various orientations of the external magnetic field (**B**) in the magnetic *ZX* plane in the 77–400 K range. [The magnetic *Z*, *X*, and *Y* axes are defined to be those orientations of **B** for which the extrema of the allowed line positions ($\Delta M = \pm 1$; *M* is the electronic magnetic quantum number) occur; of these the maximum splitting of the EPR lines occurs for **B** along the magnetic *Z*-axis, while the minimum splitting of EPR lines occurs for **B** along the magnetic *Y* axis.] Some additional measurements were made at Q-band (36 GHz) and 140 K.

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doi:10.1016/j.physb.2012.01.094